Search for heavy charged vector bosons decaying to a charged lepton and a neutrino with the ATLAS experiment

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Abstract

This poster presents a search [1] for new particles in events with one lepton (electron or muon) and missing transverse momentum using 20.3 fb^{-1} of proton-proton collision data at $\sqrt{s}$ = 8 TeV recorded by the ATLAS experiment at the LHC. W' and W* heavy charged vector bosons are considered as two new-physics scenarios. No significant excess beyond Standard Model (SM) expectations is observed. W' bosons with Sequential Standard Model couplings are excluded at the 95% confidence level (CL) for masses up to 3.24 TeV. W* bosons with equivalent coupling strengths are excluded at the 95% CL for masses up to 3.21 TeV. The search is also sensitive to direct production of weakly interacting candidate dark matter particles. This new-physics scenario is discussed in ref. [1] but not considered here since it goes beyond the subject of the poster.

Models

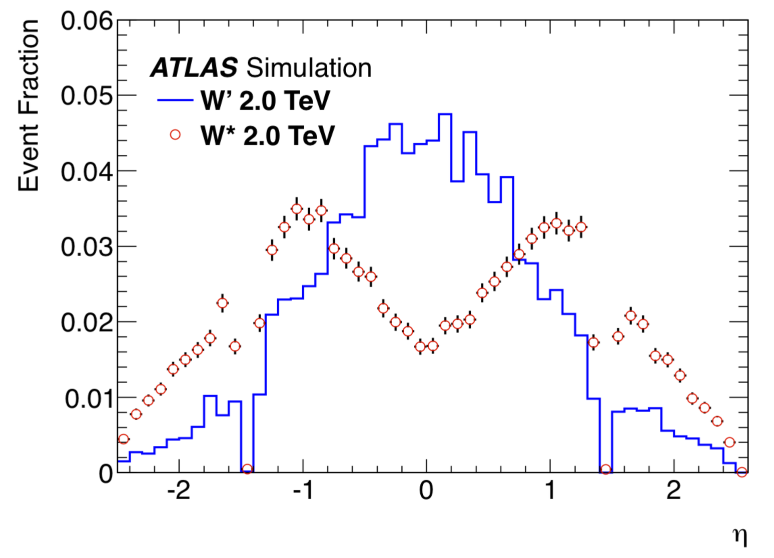
Sequential Standard Model W' [2]:

- Same couplings to fermions as the SM W boson
- Width increases linearly with the W' mass
- Coupling of the W' to WZ is set to zero

Chiral Boson W* [3]:

- Anomalous (magnetic-moment type) coupling of the W* to fermions
- Kinematic distributions significantly different from those of the W'

Reconstructed electron η distribution for W' → eν and W* → eν:



Signals and Backgrounds

- Signal processes:
  - W' → lν and W* → lν (l = e,μ)
- Background processes:
  - W → lν (l = e,μ,τ)
  - Z → ll (l = e,μ,τ)
  - Top quark ($t\bar{t}$ and single top)
  - Dibosons (WW,WZ,ZZ)
  - Multi-jet
- Evaluated using simulated Monte Carlo samples (except multi-jet)
- Normalized using the calculated cross-sections and the integrated luminosity of the data
- Multi-jet background is estimated from data

Expected number of events in each channel for m_T > 1500 GeV:

	$e\nu$		$\mu\nu$	
$W \to \ell\nu$	2.65	± 0.10	2.28	± 0.21
$Z \to \ell\ell$	0.00163	± 0.00022	0.232	± 0.005
Diboson	0.27	± 0.23	0.46	± 0.23
Top	0.0056	± 0.0009	0.0017	± 0.0001
Multi-jet	0.066	± 0.020	0.046	± 0.039
Total	2.99	± 0.25	3.01	± 0.31

Statistical Analysis and Systematic uncertainties

- For each candidate mass the signal selection efficiency (ε_{sig}), the expected number of background events (N_{bkg}) and the number of observed events (N_{obs}) are determined above m_{Tmin} threshold. Values of m_{Tmin} are optimized for each candidate mass
- Using Poisson statistics, the likelihood to observe N_{obs} events is:

$$\mathcal{L}(N_{\rm obs}|\sigma B) = \frac{(L_{\rm int}\varepsilon_{\rm sig}\sigma B + N_{\rm bkg})^{N_{\rm obs}} e^{-(L_{\rm int}\varepsilon_{\rm sig}\sigma B + N_{\rm bkg})}}{N_{\rm obs}!},$$

  where L_{int} is the integrated luminosity of the data sample
- Uncertainties are included by introducing nuisance parameters (L_{int}, ε_{sig} and N_{bkg}) with log-normal PDFs and integrating the likelihood over nuisance parameters
- Bayes' theorem gives the posterior probability to have signal strength σB:

$$P_{\rm post}(\sigma B|N_{\rm obs}) = N\mathcal{L}_{\rm B}(N_{\rm obs}|\sigma B)P_{\rm prior}(\sigma B),$$

  where N is a normalization factor, P_{prior} is a prior bribability chosen to be flat in σB
- P_{post} is evaluated for each mass and decay channel and used to set a limit on σB
- Inputs for the evaluation of P_{post} are L_{int}, ε_{sig}, N_{bkg}, N_{obs} and the uncertainties on the first three
- Relative uncertainty on L_{int} is 2.8 %
- As example, relative uncertainties on ε_{sig} and N_{bkg} for a W' with m = 2000 GeV used with m_{Tmin} = 1500 GeV are listed below:

	$\varepsilon_{\rm sig}$		$N_{\rm bkg}$	
Source	$e\nu$	$\mu\nu$	$e\nu$	$\mu\nu$
Reconstruction and trigger efficiency	2.5%	4.1%	2.7%	4.1%
Lepton energy/momentum resolution	0.2%	1.4%	1.9%	18%
Lepton energy/momentum scale	1.2%	1.8%	3.5%	1.5%
$E_{\rm T}^{\rm miss}$ scale and resolution	0.1%	0.1%	1.2%	0.5%
Beam energy	0.5%	0.5%	2.8%	2.1%
Multi-jet background	-	-	2.2%	3.4%
Monte Carlo statistics	0.9%	1.3%	8.5%	10%
Cross-section (shape/level)	2.9%	2.8%	18%	15%
Total	4.2%	5.6%	21%	27%

References

[1] ATLAS Collaboration, JHEP 09 (2014) 037, arXiv:1407.7494
[2] G. Altarelli, B. Mele and M. Ruiz-Altaba, Z. Phys. C 45 (1989) 109
[3] M. Chizhov and G. Dvali , Phys. Lett. B 703 (2011) 593-598, arXiv:0908.0924
[4] ATLAS Collaboration, Phys. Lett. B 705 (2011) 28–46, arXiv:1108.1316
[5] ATLAS Collaboration, Eur. Phys. J. C 72 (2012) 1–23, arXiv:1209.4446
[6] CDF Collaboration, Phys. Rev. D 83 (2011) 031102, arXiv:1012.5145
[7] https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/EXOT-2015-002/

Search Strategy

- The kinematic variable used to identify the signal is the transverse mass:

$$m_{\rm T} = \sqrt{2p_{\rm T}E_{\rm T}^{\rm miss}(1-\cos\varphi_{l\nu})}\,,$$

  where $p_{\rm T}$ is the lepton transverse momentum, $E_{\rm T}^{\rm miss}$ is the magnitude of the missing transverse momentum vector and $\varphi_{l\nu}$ is the angle between the $p_{\rm T}$ and $E_{\rm T}^{\rm miss}$ vectors
- The m_T distribution in data is examined for a significant excess above SM expectations
- If no excess is found then limits are set on the cross-section times branching fraction (σB) using Bayesian approach

Event Selection

Electron channel:

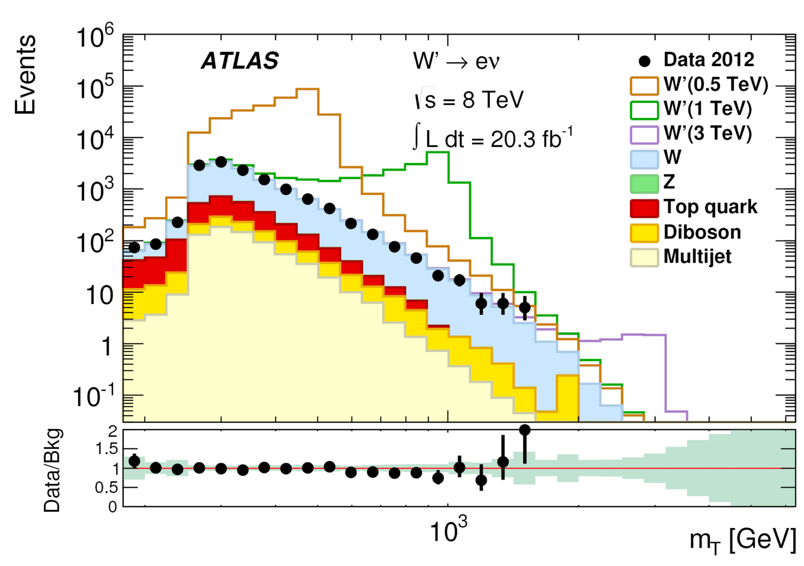
- p_T > 125 GeV
- |η| < 2.47 (excluding 1.37 < |η| <1.52)
- $\Sigma E_T^{Calo} < 0.007 \times p_T$ + 5 GeV (in a cone ΔR < 0.2† around the electron)
- Missing E_T > 125 GeV
- Veto events with additional electrons with p_T > 20 GeV

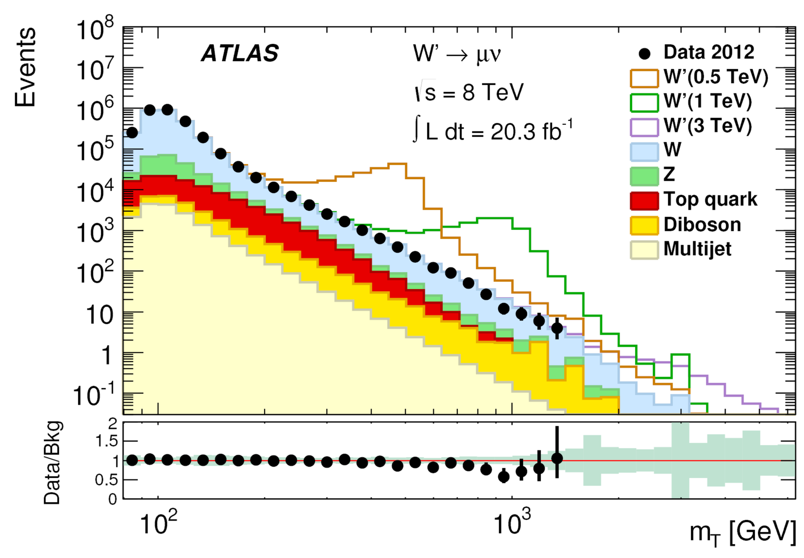
Muon channel:

- p_T > 45 GeV
- |η| < 2.0 (excluding 1.0 < |η| <1.3)
- $\Sigma p_T^{Track} < 0.05 \times p_T$ (in a cone ΔR < 0.3† around the muon)
- Missing E_T > 45 GeV
- Veto events with additional muon candidates with p_T > 20 GeV

$^{\dagger}\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\varphi)^2}$

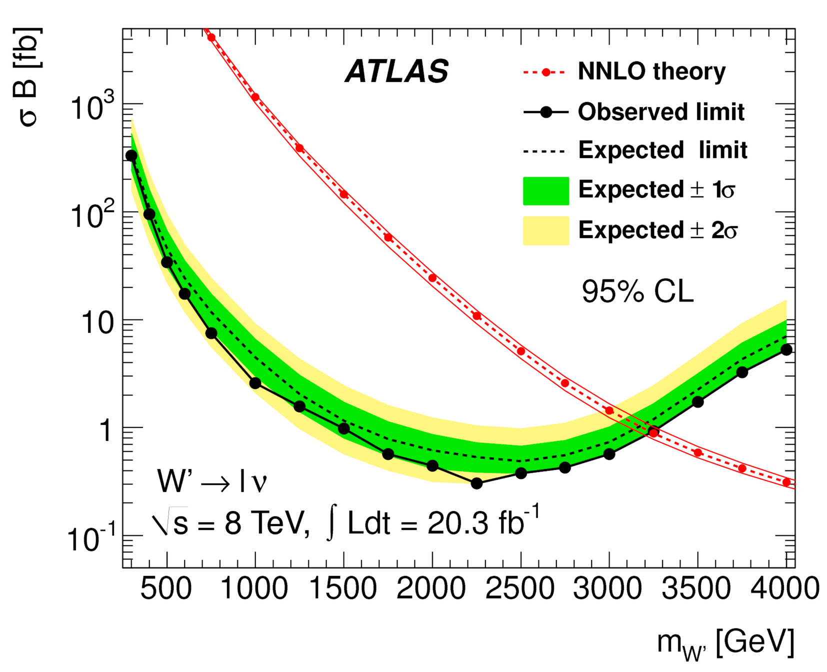
Transverse mass distributions of the selected events:

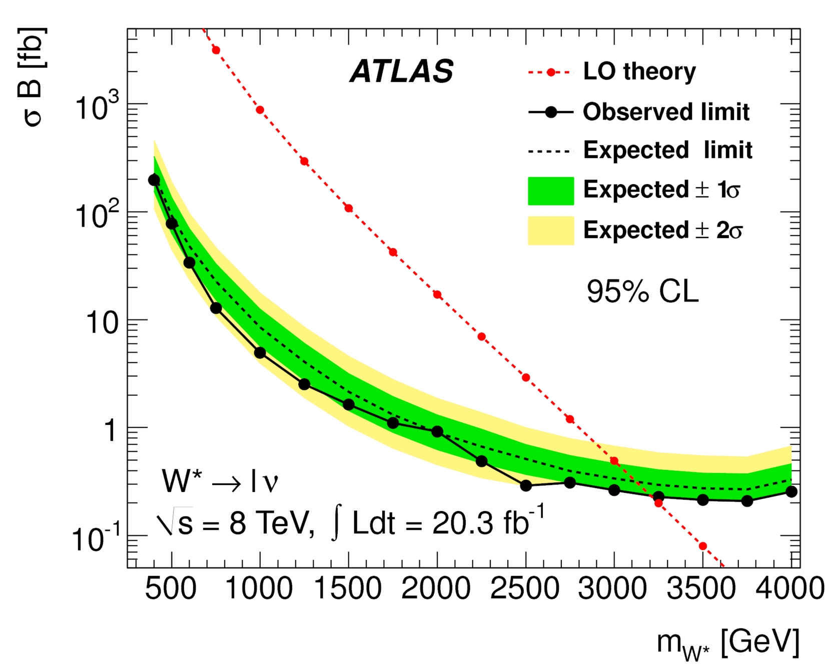




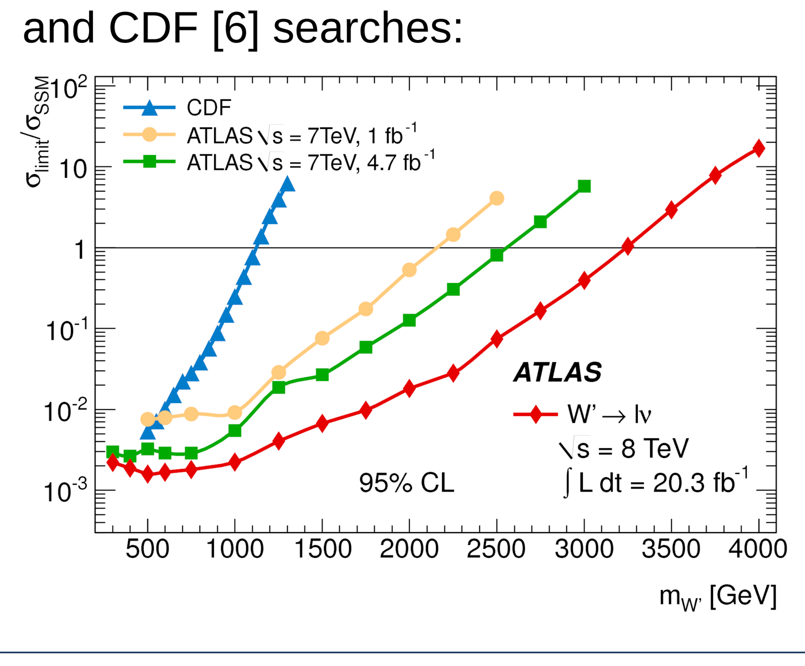
Results

- The numbers of observed and expected events are in good agreement
- No evidence for the observation of either W' → lν or W* → lν
- 95% CL limits are set on σB for two decay channels and combined assuming the same branching fraction for each:





- Normalized limits $\sigma_{limit}/\sigma_{SSM}$ can be compared to previous ATLAS [4,5] and CDF [6] searches:



- 95% CL lower limits on W' and W* masses:

Decay	$m_{W'}$ [TeV] Exp.	$m_{W'}$ [TeV] Obs.	m_{W^*} [TeV] Exp.	m_{W^*} [TeV] Obs.
$e\nu$	3.13	3.13	3.08	3.08
$\mu\nu$	2.97	2.97	2.83	2.83
Both	3.17	3.24	3.12	3.21

- The search is resumed in 2015 using pp collision data at $\sqrt{s}$ = 13 TeV. First public plots based on 78 pb^{-1} of the data are available in ref. [7]

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ATLAS EXPERIMENT